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APPARATUS FOR AND METHOD OF TREATING AND TRANSPORTING FLUID-ENTRAINABLE PARTICLES ;

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ABSTRACT:

1406650 Mixing apparatus; Fluid-energy mills; Pneumatic separation CROWN ZELLERBACH INTERNATIONAL INC 6 Dec 1972 [31 Jan 1972] 56376/72 Headings B1C, B2A and B2H [Also in Divisions B1, B8 and F4] In apparatus for mixing de-agglomerating, separating and transporting fluid-entrained particulate material, the fluid enters at 43 and issues from an annular slit 37, entraining particles from hopper 10 and attaching itself to surface 35 whereby it passes along a first flow path 11 at the end of which it encounters a fluid curtain issuing from an annular slit 16. Particles undergo de-agglomeration and intense mixing in the zone of the curtain. Fluid from the slit 16 together with any particles entrained thereby then attaches itself to the surface 17 whereby it is guided into a second flow path 21 and the entrained particles art deposited in a collector 22. Particles having sufficient momentum at the end of the first flow path may pass through the curtain and fall into a collector 27; or if their momentum is greater still may be entrained by fluid issuing from an annular slit 26, which attaches itself to a surface 68, 24 and conveys the particles through a conduit 25 to a further collector (not depicted). The widths of the slits 37, 16, 26 are screw-threadedly adjustable (Figs 2 and 3, not shown) and the assembly consisting of nozzle assembly 15 and arm 95, (together with conduit 25 and collector 27) may be axially adjusted by crank 98 to position slit 16 in relation to the flow attachment surface 17. The collector 27 may be open at 90 as shown, to entrain atmosphereic air, or may be closed and have a tangential inlet (92, Fig 5 not shown) for fluid entrained or under pressure, and a tangential outlet (93) for fluid and entrained particles. Examples and applications relate to the. separation of polyethylene fibres from water and sand, de-agglomeration of polyethylene fibres intended for making synthetic paper, separating and opening of rayon staple fibres, mixing of fibres of polyethylene and rayon, the coating of transported particles by vapours or powders, and the transport of ground metallic ores, metal particles, wood chips, cellulose fibres and cereal grains.

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(54) APPARATUS FOR AND METHOD OF TREATING AND TRANSPORTING FLUID-ENTRAINABLE PARTICLES

(71) We, CROWN ZELLERBACH INTERNATIONAL INC., a Corporation organised and existing under the Laws of the State of Delaware, United States of America, of, One Bush Street, San Francisco, California 94119, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method of and apparatus for treating and transportation of fluid-entrainable particles.

A phenomenon known as the "Coanda effect" has been known for many years. Briefly, this phenomenon can be described as the tendency of a fluid, which emerges from a slit under pressure, to attach itself or cling to and follow a surface in the form of an extended lip of the slit, which lip recedes from flow axis of the fluid as it emerges from the slit. This creates a zone of reduced pressure in the area of the slit and so air or any other entrainable material which is in the zone will become entrained and flow with the fluid which has attached itself to the extended lip. A Coanda nozzle may, therefore, be defined as a device which utilizes this phenomenon.

It is also known that a fluid emerging from a slit under pressure will attach itself to and follow a receding deflection surface even though the surface is spaced from the slit, and such flow attachment also causes a zone of reduced pressure and subsequent entrainment of air or other material in the zone of the attached flow.

Even though Coanda nozzles have been effectively used rapidly to transport particulate material, it is often desirable, especially if the material is somewhat agglomerated, to subject the material to a greater rupturing or disseminating force than is achieved by mere rapid in-line movement of entrained material, and it would be desirable to accomplish this during transportation rather than require a separate operation to do so. Materials having different characteristics (e.g. different specific weights) are often transported in mixed form, and it would be desirable to provide at least some degree of separation or classification of the material during transportation thereof. Other times, it is desirable to provide good mixing of the material being transported during transportation thereof.

In accordance with one aspect of the present invention there is provided a method of treating fluid-entrainable particles including the steps of advancing the particles entrained in a fluid from an inlet to an outlet end of a first flow path; and providing from a slit a high velocity fluid-curtain barrier which intersects the first flow path at the outlet end thereof, the fluid curtain being directed onto a substantially curved flow-attachment surface with any particles entrained by the fluid of the fluid curtain being carried along a second flow path defined by said flow-attachment surface due to the Coanda effect.

A further aspect of the invention provides apparatus for treating and transporting fluid-entrainable particles comprising a first flow path having inlet and outlet ends, means for causing particles with an entraining fluid to be advanced along the first flow path from the inlet to the outlet end thereof; a fluid-curtain generator adjacent the outlet end of the first flow path having an exit slit for providing discharge of fluid from the slit to form a high velocity fluid-curtain barrier intersecting the first flow path, and a substantially curved flow-attachment surface spaced from the fluid-curtain generator and so positioned in relationship with the position of

the fluid curtain generator, that during use of the apparatus the fluid of said curtain and any particles entrained thereby follow said flow-attachment surface due to the coanda effect in a second flow path. Preferably the first flow path is provided by a first nozzle assembly provided with internal and external particle-flow directing surfaces, said internal surface having a particle inlet end and a particle outlet end, the fluid curtain generator comprises a second nozzle assembly including a fluid-exit slit positioned adjacent the outlet end of the first nozzle assembly, and means for directing fluid through the slit to provide a fluid curtain moving in a direction intersecting the first flow path; and the external particle-flow-directing surface of the first nozzle comprises the external flow-attachment surface.

The present invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a side elevational view, with parts broken away for clarity, of apparatus embodying the invention for treating and transporting fluid entrainable particles;

Figure 2 is an enlarged side view, with parts broken away for clarity, of a nozzle assembly used in the apparatus of Figure 1;

Figure 3 is an enlarged side view, with parts broken away for clarity, of another nozzle assembly as used in the apparatus of Figure 1;

Figure 4 is a sectional view taken on the line 4—4 of Figure 2;

Figure 5 is a reduced sectional view taken on the line 5—5 of Figure 1, with parts removed for clarity; and

Figure 6 is a sectional view taken on the line 6—6 of Figure 1.

Referring to Figure 1, particulate material to be transported is supplied from a hopper 10 to a first flow path 11 for the material, which flow path is defined by the internal surfaces of a first nozzle assembly 12. This material is entrained and rapidly transported in a suitable fluid, such as air, in the direction of the arrow leading from inlet end 13 to outlet end 14 of the first flow path 11.

A fluid-curtain generator in the form of a second nozzle assembly 15 is positioned adjacent the outlet end of the first flow path so as to generate a high velocity fluid curtain, such as high velocity air, which emanates from a fluid-exit slit 16 in the second nozzle assembly, to provide a fluid-curtain barrier which intersects the first material flow path 11 at the outlet end thereof. The fluid curtain is directed from the slit 16 to a flow-attachment surface 17, which at one end is in the form of a convexly curved, external end of nozzle 12 and the convexly curved end is spaced in close enough proximity to the slit 16 for the fluid curtain to attach itself to and follow surface 17 due to the aforementioned Coanda effect. In preferred form, as illustrated, the fluid curtain moves in a direction intersecting the first flow path at an angle substantially perpendicular thereto. The fluid curtain carries any entrained particles with it as it follows along external nozzle surface 18 in the direction of the arrows. This fluid curtain entrains additional air from an external source (such as the atmosphere) which enters from around the end 19 of shroud 20 further to reduce the particle concentration by entrainment of additional air. The internal surface of shroud 20 together with the external surface 18 of the first nozzle assembly define a second flow path 21 having an inlet end in communication with the outlet end of the first flow path 11. The flow-attachment surface is so positioned as to change the direction of flow of any particles entrained by the curtain at least 90 degrees with respect to the direction the particles were travelling in the first flow path.

In the preferred embodiment illustrated in the drawings, any particles which have been entrained by the fluid curtain then move along the second flow path in the direction of the arrows, and the direction of movement of the particles in the second flow path 21 is opposite or 180 degrees to the direction the particles have moved along the first flow path 11.

The entrained particles are moved from the second flow path into any suitable collector 22. While the type of collector is not critical, it has been illustrated as a receptacle having a screen 23 to permit air to pass out of the receptacle while retaining the particles therein.

At the outlet end of the first flow path 11, prior to encountering the fluid curtain, the particles are at a rather high velocity, preferably at least 40 feet per second (12 metres per second) when the entraining fluid is gaseous, such as air. The fluid curtain emanating from slit 16 which intersects this flow path also is moving at a high velocity which is preferably at least 300 feet per second (90 metres per second) when a gaseous fluid, such as air, is used to provide the curtain. The particles upon contact with the fluid curtain thereby undergo a violet shock so as to cause a rupture or breaking up of any agglomerated particles. If the particles have not achieved sufficient momentum to penetrate the fluid curtain, they will be entrained in the fluid curtain and move along the second flow path 21. There may, however, be particles which have achieved sufficient momentum in the first flow path 11 to penetrate the fluid curtain. These particles, after penetrating the curtain, are moved by suitable means for conveying them in a direction away from the second flow path of the entrained particles.

Actually, the particles which penetrate the curtain may be classified further into two general types, namely, those which have developed sufficient momentum to penetrate the fluid without substantial deflection of the particles, and those which are partially deflected by the air curtain, but which, due to centrifugal force, do not follow the air curtain but are expelled therefrom in a direction extending substantially 90 degrees from the direction of flow in the second flow path 21. This further classification is optional and, if desired, all of the material which penetrates and is not moved along the second flow path 21 could be collected into a single fraction.

To summarize, use of the described apparatus in its preferred embodiment not only has capability of exerting forces by contact of particles with the fluid curtain which causes deagglomeration and intense mixing in the zone of the curtain, but also has capability of classifying particles into three general fractions, depending on the momentum achieved by the particles at the outlet end 14 of the first flow path. A first fraction are the particles which do not develop sufficient momentum to penetrate the curtain or have lost inertia due to deagglomeration, and the particles in the first fraction are entrained by the fluid curtain and moved along the second flow path 21. A second fraction are those particles developing sufficient momentum to penetrate the curtain without being substantially deflected, and the particles in the second fraction enter the zone between suitable conveying means in the form of another Coanda flow-attachment surface 24 and a shroud 25 where they are moved to any suitable collector. Fluid for entraining this second fraction is supplied from a slit 26 which is located on the opposite side of the fluid curtain supplied by slit 16 from the first nozzle assembly 12. A third fraction are those particles developing an momentum between that developed by the first and second fractions. This third fraction is expelled from the air curtain into a suitable collector 27.

In order to obtain an understanding of the structural detail of a preferred embodiment for the first nozzle assembly 12 supported within the generally cylindrical shroud 20, reference should be made to Figures 3 and 6, viewed in connection with Figure 1. The shroud 20 is supported from any suitable supporting base 28 through the medium of a clamp member 29.

The first nozzle assembly 12 has a main body portion in the form of an elongated diffuser member 30 which is supported concentrically within and spaced from the inner surface of shroud 20. The diffuser member is annular in cross-sectional configuration in that it has a generally cylindrical outer surface 18, and an inner surface 31 which diverges from a throat portion 32 to outlet end 14. The external surface of the diffuser is provided with an externally-threaded, recessed portion at the throat end 32 to receive a first fluid-exit slit-forming member 33. The member 33 is annular in cross-sectional configuration, and one end thereof is provided with internal threads 34 for receiving the threaded end of the diffuser member. As seen at Figure 3, the inner surface 35 of member 33 is convexly curved and the end 36 opposite the threaded end is utilized to define one side of a fluid-exit slit 37. This slit 37 is located adjacent the inlet end 13 of the first flow path for the material. The inner surface 35 of member 33, together with the material inlet end of diffuser 30, defines a throat portion 32 for the first material flow path in that the surface 35 converges from the slit 37 toward the throat. The opposite side of fluid-exit slit 37 is defined by an inwardly projecting flange 38 on an annular, external slit-defining member 39. A recessed external surface 40 on member 33, together with internal surface 41 on member 39, defines a fluid-pressure chamber 42 which is in communication with slit 37, and the chamber receives fluid, such as air, under pressure from a suitable fluid supply line 43. The fluid under pressure therefore emerges from the slit and, due to the Coanda effect, attaches itself to and follows surface 35 in a converging path to the throat 32. From the throat, the flow path diverges to the outlet end 14 of the nozzle assembly 12. This rapidly moving air establishes a zone of reduced pressure so that it entrains additional air and any particulate material located in the zone on the opposite side of slit 37 from surface 35. Particles entrained by this fluid are thereby rapidly transported from inlet end 13 to outlet 14 of the first flow path defined by internal surfaces of the first nozzle assembly.

It is desirable to provide means for adjusting the size of slit 37; and, to accomplish this, there is a threaded connection at 44 between the members 33 and 39. Therefore, if member 39 is turned in one direction, the slit size is increased, and if it is turned in the other direction, the slit size is decreased. In order to permit an operator to ascertain the extent of increase or decrease of the slit size without actual measurement, a spring-biased detent 45 extends slightly from the recessed surface of diffuser member 30. Cooperating with the detent 45 is a plurality of countersunk portions 46 formed in and equidistantly spaced around the end of member 39. If, for example, there are thirty-six countersunk portions, the operator will know that the member 39 has to be turned 10 degrees to move the detent from one countersunk portion into the one

next adjacent. Because of the threaded connection of member 33 to member 39, the operator can readily ascertain that each turn of 10 degrees, depending on the direction, will increase or decrease the size of slit 37 a predetermined amount, depending on the thread pitch in the threaded connection. A sealing ring 47 is provided between the outer surface of member 33 and the inner surface of member 39.

To complete the outlet end 14 of the nozzle assembly 12, an annular member 48 is fixed thereto by fasteners 49. The member 48 has a convexly-curved, external surface to provide the aforementioned flow-attachment surface 17 for the fluid curtain which exits from slit 16 in the second nozzle assembly 15.

A conical member 51 is secured to member 39 by appropriate fasteners 52, and the external converging surface of this conical member, therefore, acts as a diffuser in the sense that the cross-sectional area of the second flow path 21 is gradually increased as the particles move in a direction toward the point 53 of the conical member. A material supply duct 54 leads to an internal cavity 55 in the conical member, and this cavity is in direct communication with the first flow path 11 leading from slit 37 continually to supply material to be transported to the zone adjacent the slit for entrainment of such material by fluid exiting from the slit because of the aforementioned Coanda effect.

Structural details of a preferred embodiment of a second nozzle assembly 15 are illustrated at Figure 2. A generally cylindrical outer fluid conduit member 56 has a fluid supply duct 57 in communication therewith, and an exterior collar 58 having a sloping exterior surface 59 extends concentrically around and is secured to the outer surface of the conduit 56. An inner, generally cylindrical, fluid conduit member 60 is supported concentrically within and spaced from the outer member 56, and this inner conduit is in communication with a supply duct 61. An extension 62 for conduit 60 is utilized to convey fluid under pressure from the conduit 60 to the fluid-exit slit 16 *via* openings 63 which lead to a cavity 64 in communication with this slit 16. The extension member 62 is connected to conduit 60 by an annular connector member 65. External, recessed, surface portions 66 of the connector member 65 are threaded to receive the internal threads of annular fluid-exit slit-forming member 67 which has a convex outer surface portion 68 leading away from slit 26 to form one boundary for this slit. The member 67 has countersunk portions 70 formed therein at one end thereof for receiving a spring-biased detent 71 in extension member 65 to permit adjustability of the size of slit 26 in the same manner as explained in connection with adjusting the size of slit 37 in the first nozzle member 12. A sealing ring 72 is provided between the outer surface of connector member 65 and the inner surface of member 67.

Spacer rings 73 are positioned around extension member 62 to wedge a ring-like fluid-exit slit-forming member 74 into place between a circumferential external flange 75 on the extension member 62 and a circumferential external flange 76 on connector member 65.

Surface 77 on flange 75 defines one boundary of fluid-exit slit 16. The other boundary of slit 16 is defined by an extension lip 78 on a collar 79, which collar is threaded onto external threads 80 on extension member 62 so that the size of slit 16 can be adjusted by turning collar 79 in relation to member 62. The flange 75 and collar 79 have complementary, generally cylindrical, external surfaces and are of such a size so that the slit 16 can be placed concentrically within the same plane as the plane defined by the extreme left end (as viewed in Figure 1) of flow-attachment surface 17.

Means for permitting the operator to determine the extent of increase or decrease in the size of slit 16 is provided by a spring-biased detent 81 in surface 82 of collar 79, which detent is adjustably received in countersunk portions 83 in ring-like member 84, the latter member also being threaded onto the extension member 62. A sealing ring 85 is provided between the outer surface of member 62 and the inner surface of member 79. A nose cone 86 is threaded onto the extreme right end (as viewed at Figure 2) of extension member 62. As seen at Figure 1, the nose cone projects from slit 16 concentrically into the end of the first nozzle 12, and the cone 86 serves as a guiding surface causing particles in the first flow path to be moving at substantially right angles to the fluid curtain when contact is made with the curtain.

Fluid under pressure reaches chamber 87 supplying fluid to the slit 26 via openings 88 through connector member 65. Fluid exiting from slit 26 attaches itself to surface 68 and follows this surface due to the aforementioned Coanda effect. This attached fluid entrains additioned air and any particles which are in the vicinity of the slit. Externally spaced, cylindrical shroud 25, together with surface 24, defines a flow path for material moving along surface 24 in the direction of the arrows (Figure 1).

As indicated above, collector 27 is utilized to collect those transported particles which have not developed sufficient momentum at the outlet of the first nozzle 12 to continue in a straight path so that the particles are deflected by the air curtain and expelled in-

to this collector. As illustrated at Figures 1 and 5, the collector 27 has a curved, inner circumferential surface 89 which cooperates with back wall 89*a* so as to only partially enclose the space between shrouds 20 and 25, leaving a space 90 for additional air to be entrained from the atmosphere. Such entrainment of additional air is caused by flow attachment on surfaces 17 and 24 by air exiting from slits 16 and 26. Optionally, an enclosed chamber could enclose space 90 with air being supplied under pressure to the chamber. In this modification an internal, curved divider 91 in the collector defines an inlet 92 for receiving air to be entrained through this inlet or received under pressure, and an outlet 93 for removing air and any material entrained thereby. The air from inlet 92 follows a tangential swirling flow path around the inner surface of the collector and leaves through outlet 93 carrying entrained material with it. Centrifugal forces throw the particulate material against surface 98 and the flow causes the material to follow this surface to outlet 93. Instead of using a positive pressure air to supply inlet 92, it is possible to utilize a Coanda nozzle (not shown) in outlet 93 which directs air and entrained material outwardly for removal from the collector.

An L-shaped supporting frame member 94, which is generally rectangular in cross-section, is secured to the clamp 29 adjustably to support the second nozzle assembly 15 therefrom. The supporting arrangement is such that the first and second nozzle assemblies are adjustably supported relative to each other to permit adjustment of the position of the fluid-exit slit 16 relative to external flow-attachment surface 17 of the first nozzle assembly. A complementary L-shaped supporting frame member 95 extends through shroud 25 and is secured at one end to the second nozzle assembly 15. The other end of the frame 95 has a nose portion 96 having a thread aperture 97 extending therethrough and, as is clear from Figure 1, the end of frame 95 is snugly positioned within one leg of frame 94. A crank arm 98 is rotatably supported on frame 94, and the crank is used to turn a threaded shaft 99 which is received in threaded aperture 97. Thus rotation of crank arm 98 will impart horizontal movement to second nozzle assembly 15 with respect to first nozzle assembly 12 and so this provides means for adjusting the position of exit slit 16 on the second nozzle assembly 15 relative to the flow-attachment surface 17 on the first nozzle assembly 12.

Reference should be made to Figure 1 for illustration of proper relative positioning of the component parts of the apparatus of this invention. The slit 16 should be in approximately the same plane as a plane into which all points on the extreme left tip (as viewed at Figure 1) of the attachment surface 17 would fall. It is possible, however, to obtain flow attachment of the fluid curtain from slit 16 onto surface 17 by moving the slit as much as one-half inch (1.27 cms) to the left of the plane. It is usually not desirable to move the slit to the right of the plane because, while it is still possible to get some flow attachment of the fluid curtain onto surface 17, positioning of the slit to the right of this plane generates back pressure and instability of flow in the first nozzle assembly 12.

As has been indicated above, means are provided for adjusting the width of slits 16, 37 and 26. It is desirable that this range of adjustability permits the slit width to be adjusted between a range of .001 inch to .150 inch (0.0025 cms to 0.38 cms). For most uses presently contemplated, the slit width which is chosen will lie between 0.003 inch (0.0075 cms) and .050 inch (0.125 cms).

For a given slit width, an increase in the pressure of fluid that is supplied to the slit will increase the velocity of the fluid as it exits from the slit and moves over its flow attachment surface; and, therefore, the velocity imparted to the material entrained in this fluid will increase. Pressures that may be used in supplying transporting fluid to the slits may vary over a rather wide range, such as between 1 psig and 400 psig (0.07 and 28 kilo/sq. cm.) depending on the velocity it is desired to achieve and the nature of the operation desired to be performed on the material being transported. For most uses presently contemplated, the pressures of the fluid supplied to the slits will lie between about 5 psig and 100 psig (0.35 and 7 kilo/sq. cm).

It is important that the velocity of the fluid with its entrained flow supplied from slit 37 when it reaches the outlet end 14 of the first flow path 11 be not so great as to cause detachment of the fluid curtain supplied by slit 16 onto surface 17. Otherwise, none of the material would follow the second flow path 21. Therefore, in most instances, the operator will select the pressure he desires for fluid exit from slit 16, and initially cause fluid to exit from this slit and attach itself to follow surface 17. The operator will then gradually raise the pressure of the fluid exiting from slit 37 until a value is reached where the flow of the fluid curtain supplied from slit 16 detaches from the surface 17. This is the limiting pressure to slit 37. For the slit sizes chosen, the fluid supplied to slit 37 must then be at a pressure less than would cause flow detachment from surface 17. Conversely, an operator could first predetermine a required material through-put rate achieved by adjusting pressure and slit size for slit 37. The opera-

tor may then gradually raise the pressure and/or adjust slit size of exit slit 16 until a condition of flow attachment of the curtain from slit 16 to surface 17 is obtained.

As indicated above, the flow velocities, as governed by pressures and slit sizes, chosen for the entraining fluid in flow path 11, as compared to the flow velocity of the fluid curtain from slit 16, will depend on the type of operation that it is desired to perform on the material being transported. If, for example, the material being transported includes a mixture of two types of material (one type of which is capable of developing higher momentum than the other, and if separation of the two types of material is desired, then it will be desirable to establish as high a velocity as possible in flow path 11 without causing detachment of the curtain from attachment surface 17.

On the other hand, if it is mostly desired to cause a breaking up, mixing or deagglomeration of particles being transported, then the velocity of the fluid curtain from slit 16 will be adjusted to be high in relation to the velocity of the particles transported in first flow path 11. In the latter instance, it will be highly preferable to utilize a higher pressure for the fluid that supplies slit 16, as compared to the pressure of the fluid that supplies slit 37.

While, as indicated above, velocities imparted to the entrained material may be varied, it is preferable to adjust the pressure and slit size for the material to achieve a velocity of at least 40 feet per second (12 metres per second) at the outlet end of flow path 11, and to adjust pressure for the fluid curtain from slit 16 to achieve a velocity of at least 300 feet per second (90 metres per second), these stated velocities being for most types of particles and where a gaseous entraining fluid is used to transport the particles.

The specific type of material or particles to be transported, so long as they are entrainable in a fluid, are not critical. The particles may be any fluid-entrainable materials which may be entrained in the transporting fluid at the velocities employed. Thus, in certain instances, it may be desirable to transport such particles as ground metallic ores, metal particles, cereal grains, wood chips, cellulose fibres, fine powders, and many other materials by use of the described method and apparatus.

Notwithstanding the fact that many additional types of particles may be transported, examples which are hereinafter presented illustrate the use of this invention with certain types of material, the treatment of which has been found to be especially advantageous. When reference is made in these examples to polyethylene fibres, such fibres are of a type such that after they have been suitably prepared for making synthetic paper, are of papermaking size, i.e., about 0.2 to 3 millimetres in length and have a diameter or width of about 20 to 400 microns. When reference is made to rayon staple fibres, such fibres are $\frac{3}{8}$ inch (0.95 cms) in length and 3 denier. The rayon staple, as supplied is in the form of many individual fibres closely packed together to form fibre bundles.

With further reference to the examples which follow, when reference is made to the "F" fraction it means that fraction of material which has been entrained by the fluid curtain and has been collected by the collector 22. The "R" fraction is a fraction which has penetrated the curtain and is collected downstream of the surface 24. The "C" fraction is a fraction which has been collected in collector 27.

In the examples which follow, the apparatus which was used had the following physical and operating characteristics (unless otherwise noted):

	Size inches (cms)	*Pressure psig (kilo/sq. cm).*
Pressure supplied by line 43		30 (2.1)
Width of slit 37	0.006 (0.015)	
Length of nozzle from slit 12 to end 14 ...	20.0 (50.8)	
Diameter of throat 32	0.6 (1.52)	
Internal diameter of diffuser at outlet end 14	1.53 (3.89)	
Diameter of external surface 18	3.00 (7.62)	
Internal diameter of shroud 20	5.50 (13.95)	
Pressure supplied to slit 16		30 (2.1)
Width of slit 16	0.020 (0.051)	
External diameter of slit 16	0.750 (1.905)	
Horizontal distance (to the left as viewed at Figure 1) of slit 16 to the vertical plane of the extreme left end of surface 17 ...	0.06 (0.152)	
Pressure supplied to slit 26		30 (2.1)
Width of slit 26	0.003 (0.008)	
External diameter of surface 24 (largest) ...	1.8 (4.57)	
Internal diameter of shroud 25	4.0 (10.02)	
Horizontal separation distance of ends of shrouds 20 and 25	1.5 (3.8)	
Internal diameter of collector 27	14.0 (35.5)	
Internal diameter of flange 89a	10.0 (25.4)	

Example 1

In this example, wet synthetic polyethylene fibres were intimately mixed with sand and the mixture was transported through the apparatus described above. Individual weights of the fibres, water and sand in the input mixture and, also in each of the collected fractions were determined. Measurements were made of the particle size of the sand in the input mixture and in each fraction. The specific weight of the fibres is about 0.95, and the specific weight of the sand is about 2.56. The results are tabulated in the following Table I.

TABLE I

	Input	*Fraction* "*F*"	"*C*"	"*R*"
Weight of fibre (gm) dry basis	51.77	30.60	14.95	6.22
Weight of Water (gm)	18.23	2.40	5.79	5.05
Weight of sand (gm) dry basis	217.00	4.00	51.00	162.00
Sand-particle size:				
% retained in 35-mesh screen	26	25	12	28
% retained in 100-mesh screen	72	70	83	71
% passed through 100-mesh screen ...	2	5	5	1

The foregoing data clearly indicates that most of the fibres, which have substantially less specific weight than the sand, are entrained by the fluid curtain and pass to the "F" fraction. The sand develops sufficient inertia to permit it to penetrate the fluid curtain, as is demonstrated by the fact that, of the total sand transported, less than 2% was carried with the fibres to the "F" fraction. Much less sand is contained in the "C" fraction than in the "R" fraction. The data further indicates that there is a tendency for the coarser sand to go into the "R" fraction and the finer sand to the deflected and captured in the "C" fraction. Moisture was removed from the fibres which passed to the "F" fraction, as evidenced by the fact that the input fibres were only 74% O.D. (oven dry), but the fibres in the "F" fraction were 93% O.D. (oven dry).

Example 2

In this example, polyethylene fibres were utilized in a mixture which also had some small polymer chunks therein, the chunks being heavier than the individual fibres. Included, also in the mixture were some severely entangled fibres. A sample from this mixture (prior to being transported through the apparatus described above) was used to make a 6.25-inch (15.9 cm) diameter, 36 pound/3000 sq. ft. (58.6 gms/sq. metre) basis weight, handsheet in a conventional manner by dispersing the mixture in water in a vessel, shaking the vessel one hundred times, and then using the dispersed mixture to form the handsheet on a forming wire in a conventional handsheet mould. The handsheet was calendered at 150 pounds per lineal inch (26.8 kilo/cm). The presence of polymer chunks and agglomerated fibre bundles in the handsheet is indicated by the extent and size of transparent spots that appear in the handsheet after such calendering, because such chunks and bundles have a tendency to transparentize. After passing another sample from the same mixture through the apparatus described above, handsheets were also formed and calendered from the "F", "R" and "C" fractions. Measurements were made of transparent spots formed in each handsheet by using a template to measure the size and by counting the number. The results are tabulated in the following Table II.

TABLE II

	Size and Number of Transparent Spots Over $8mm^2$	$8mm^2$	$4mm^2$	$2mm^2$	Less than $2mm^2$
Input	45	61	96	*100	*300
"R" Fraction	7	18	40	76	*200
"C" Fraction	0	13	26	*133	*500
"F" Fraction	0	0	5	25	70

* The number of 100 or over are approximations.

The above data indicates there is an overall breaking up of fibre bundles, as evidenced by the reduction in large spots in all of the treated fractions as compared to the input fraction. The data also indicates there is a tendency for the "R" fraction to obtain the larger chunks and bundles, and a tendency for the "C" fraction to obtain the smaller chunks and bundles because the smaller chunks and bundles have more of a

tendency to be deflected by the fluid curtain.

Example 3

In this example, wet polyethylene fibres which were 57% O.D. (oven dry) with a moisture content of 43% were passed through the apparatus as described above, except that the pressure of fluid supplied to fluid-exit slits 16 and 37 were varied. The pressure P_1 is the air pressure supplied to slit 37 and the pressure P_2 is the air pressure supplied to slit 16. The pressure supplied to slit 26 is the same as that supplied to slit 16. Measurements were made of the percentage of the original fibres supplied which were collected at each of the fractions for each pressure combination, and measurements were made of the moisture content on an O.D. (oven dry) basis for the "F" fraction. The results are tabulated in the following Table III.

TABLE III

P_1 psig (kilo/sq. cm)	P_2 psig (kilo/sq. cm)	% "F" fraction	% "R" fraction	% "C" fraction	% O.D. "F" fraction
30 (2.1)	50 (3.5)	74.0	18.2	8.6	67
40 (2.8)	40 (2.8)	65.7	26.2	8.8	63
50 (3.5)	30 (2.1)	56.3	39.3	8.7	70

The above data indicates that as the pressure from slit 37 increases, compared to the pressure from slit 16, the velocity imparted to the fibres also increases in the first flow path, and so more fibres penetrate the fluid curtain. Data also indicates that some drying of the fibres takes place. The amount in the "F" fraction could be increased by moving the shroud 20 to the left (as viewed at Figure 1) to intercept some of the particles that otherwise would pass to the "C" fraction. If pressures are held constant, an increase in the size of slit 37 will decrease the amount of material in the "F" fraction. An increase in the size of slit 16 will increase the amount of material in the "F" fraction. An increase in the amount of material in the "R" fraction can be accomplished by increasing pressure and/or slit size of slit 26.

Example 4

In this example, 116 grams of rayon staple fibres (in the form of fibre bundles, as indicated above) were placed in a graduated beaker and, without external compression, were found to occupy a volume of 0.8 litre. These fibre bundles were passed through the apparatus indicated above, except the pressure of air supplied to slits 16 and 37 was 40 psig. Sixty-seven grams of the fibres were collected as an "F" fraction, and 49 grams total was collected at the "R" and "C" fractions. The fibres collected at the "F" fraction were placed in a graduated beaker without external compression and found to occupy a volume of 6.0 litres; and, upon viewing, had the appearance of a mass of separated fibres. This indicates that the treatment was effective to break up and fluff the original fibre bundles. The "R" and "C" fractions, when placed in a beaker, occupied a volume of 1.5 litres with a visual appearance of a mixture of fibre bundles and separated fibres.

Example 5

In this example, a sample including substantially equal quantities of dry polyethylene fibres and rayon staple fibres were placed in a vessel and it was attempted to mix the fibres together by hand-shaking but only a very poor mixture was obtained. This sample was then transported through the described apparatus and a sample obtained at the "F" fraction showed the polyethylene fibres and the rayon staple fibres to be intimately mixed with each other. This suggests that the forces encountered by the particles when they contact the fluid curtain are effective to intermix different types of fibres which are of such a nature as to be both transported by the fluid curtain. Rather than using different types of fibre, it is possible to use the described method and apparatus to incorporate fine, lightweight powders into uniform admixture with fibres when both are simultaneously transported through the apparatus. It is contemplated that vapours or very fine particles functioning as coating agents for the entrained material could be added to the entraining fluid to take advantage of the mixing zone provided by the fluid curtain to coat the transported particles.

From the above it, should be clear that the described method and apparatus has utility for achieving a number of desired results in transporting and treating particulate material, depending on the nature of material being transported and the operating conditions chosen. Separation of particles capable of developing different momentum may be obtained. It is also possible to achieve good mixing and deagglomerating of particulate matter due to forces acting on the particles when they contact the fluid

curtain. Drying of wet fibrous material has also been demonstrated.

WHAT WE CLAIM IS:—

1. Apparatus for treating and transporting fluid-entrainable particles comprising a first flow path having inlet and outlet ends, means for causing particles with an entraining fluid to be advanced along the first flow path from the inlet to the outlet end thereof; a fluid-curtain generator adjacent the outlet end of the first flow path having an exit slit for providing discharge of fluid from the slit to form a high velocity fluid-curtain barrier intersecting the first flow path; and a substantially curved flow-attachment surface spaced from the fluid-curtain generator and so positioned in relationship with the position of the fluid curtain generator, that during use of the apparatus the fluid of said curtain and any particles entrained thereby follow said flow-attachment surface due to the Coanda effect in a second flow path.

2. Apparatus as claimed in claim 1, wherein the first flow path is defined by internal surfaces of a first nozzle assembly.

3. Apparatus as claimed in claim 2, wherein the means for causing the particles to be advanced comprises a feed fluid-exit slit located adjacent the inlet end of the first flow path and means for directing entraining fluid through the feed slit and along the internal surfaces in a direction from the inlet end to the outlet end of the first nozzle.

4. Apparatus as claimed in claim 3, wherein the internal surfaces converge from the feed slit to a throat portion and diverge from the throat portion to the outlet end.

5. Apparatus as claimed in claim 3 or 4, wherein the feed slit size is adjustable.

6. Apparatus as claimed in claim 2, 3, 4 or 5, wherein said flow-attachment surface comprises an external end of the first nozzle assembly.

7. Apparatus as claimed in claim 6, which further includes a shroud spaced outwardly from the external surface of the first nozzle assembly, said shroud and external surface together defining said second flow path having an inlet end in communication with the outlet end of the first flow path.

8. Apparatus as claimed in claim 7, wherein the direction of flow in said second flow path extends opposite to the direction of flow in said first flow path.

9. Apparatus as claimed in any preceding claim, wherein the fluid-exit slit of the fluid-curtain generator is adjustable as to its size.

10. Apparatus as claimed in any preceding claim, wherein the second flow path is in communication with an external air source for providing additional air to further reduce particle-air concentration by entrainment of the additional air.

11. Apparatus according Claim 1, wherein the first flow path is provided by a first nozzle assembly provided with internal and external particle-flow directing surfaces, said internal surface having a particle inlet end and a particle outlet end; the fluid curtain generator comprises a second nozzle assembly including the fluid-exit slit positioned adjacent the outlet end of the first nozzle assembly, and means for directing fluid through the slit to provide a fluid curtain moving in a direction intersecting the first flow path, and the external particle-flow-directing surface of the first nozzle comprises the external flow-attachment surface.

12. Apparatus as claimed in Claim 11, wherein the particle outlet end of the first nozzle assembly is circular in cross-sectional configuration, and external surfaces of the second nozzle assembly adjacent the fluid-exit slit are substantially cylindrical, the slit being positioned in substantially the same plane as that of the circular, particle-outlet end of the first nozzle assembly.

13. Apparatus as claimed in Claim 11 or 12, wherein the first and second nozzle assemblies are adjustably supported relative to each other to permit adjustment of the position of the fluid-exit slit of the second nozzle assembly relative to the external flow-attachment surface of the first nozzle assembly.

14. Apparatus as claimed in Claim 11, 12 or 13, wherein a shroud is supported in spaced relationship from the external particle-flow-directing surface of the first nozzle assembly to define a boundary for the second flow path for any particles entrained by the fluid curtain to follow the flow-attachment surface.

15. Apparatus as claimed in any one of claims 11 to 14, which further includes means for causing any particles which penetrate the fluid curtain to be conveyed in a direction away from the second flow path.

16. Apparatus as claimed in Claim 15, wherein said means for causing conveying of particles away from the second flow path includes a fluid-exit slit located on the opposite side of the fluid curtain from the first nozzle assembly for directing fluid in flow-attached relationship onto a flow-attachment surface.

17. Apparatus as claimed in Claim 15 or 16, which further includes a collector device for particles which penetrate the curtain.

18. Apparatus as claimed in claim 17, wherein the collector device includes a curved, internal surface in communication with a conveying fluid inlet for supplying conveying fluid in tangential flow to the internal surface in a direction leading from

the inlet to a particle outlet for removing particles with the conveying fluid.

19. Apparatus as claimed in claim 15, wherein said means for causing conveying includes first conveying means for conveyingany particles having sufficient momentum supplied in the first nozzle to penetrate the fluid curtain without substantial deflection of the particles by the fluid curtain, and second conveying means for conveying particles having less momentum supplied in the first nozzle than the particles removed by said first conveying means, but greater momentum than particles which follow the flow-attachment surface.

20. A method of treating fluid-entrainable particles including the steps of advancing the particles entrained in a fluid from an inlet to an outlet end of a first flow path; and providing from a slit a high velocity fluid-curtain barrier which intersects the first flow path at the outlet end thereof, the fluid curtain being directed onto a substantially curved flow-attachment surface with any particles entrained by the fluid of the fluid curtain being carried along a second flow path defined by said flow-attachment surface due to the Coanda effect.

21. A method as claimed in Claim 20, wherein the particles are a mixture of particles capable of developing different momenta and which includes penetrating the fluid curtain with particles capable of developing sufficient inertia to penetrate said fluid curtain and removing such penetrating particles, and entraining for movement with the fluid curtain particles which do not develop sufficient inertia to penetrate the fluid curtain.

22. A method as claimed in Claim 20, which further includes separating particles which penetrate the fluid curtain into a first fraction which move along a path substantially coextensive with the first flow path, and a second fraction which partially turn with the fluid curtain and are then expelled therefrom.

23. Apparatus for treating and conveying fluid-entrainable particles constructed and arranged to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

24. A method of treating fluid-entrainable particles substantially as herein described with reference to the accompanying drawings.

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FIG. 6

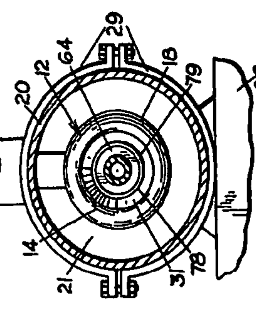


FIG. 5

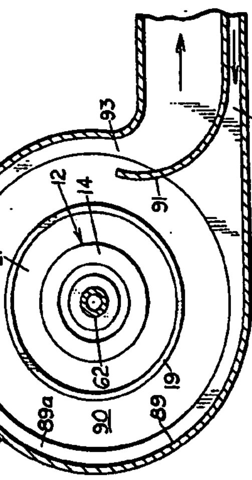
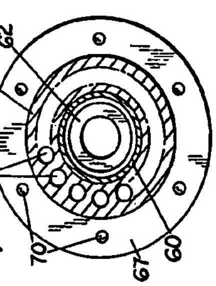


FIG. 4



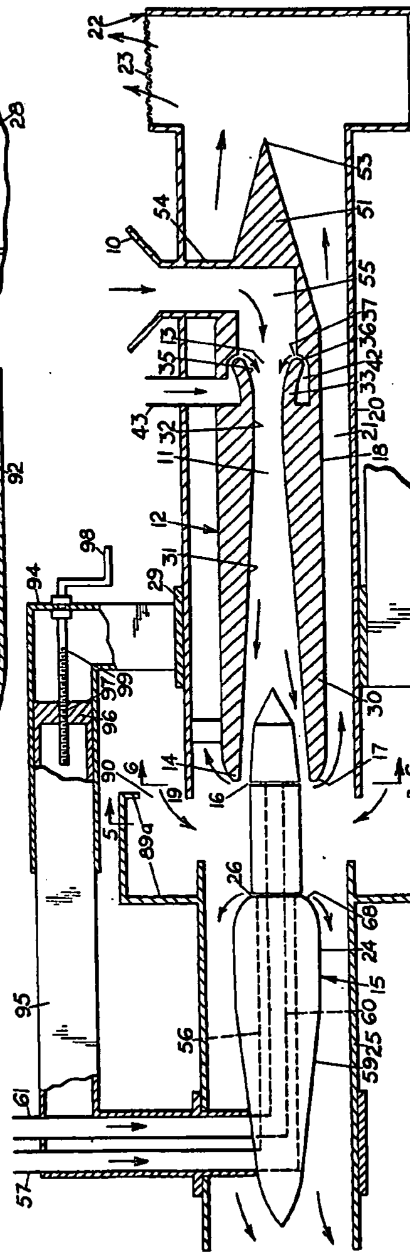


FIG. 1

1406650 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

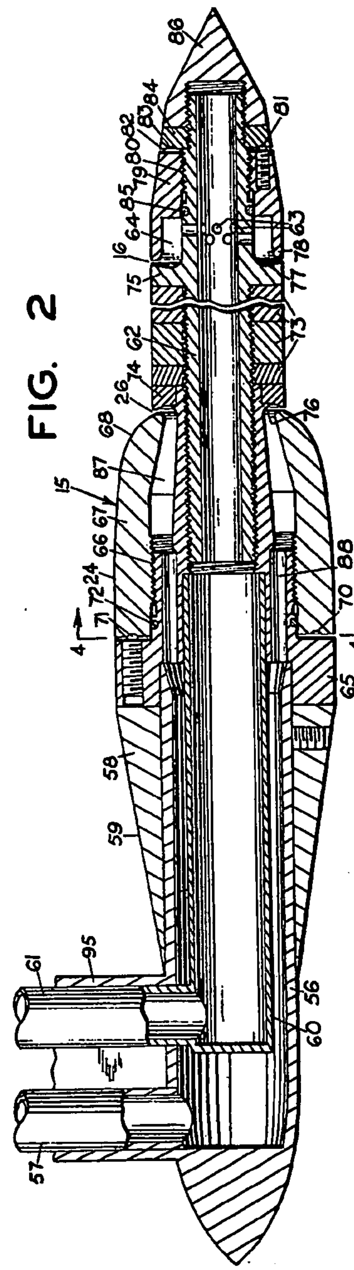


FIG. 2

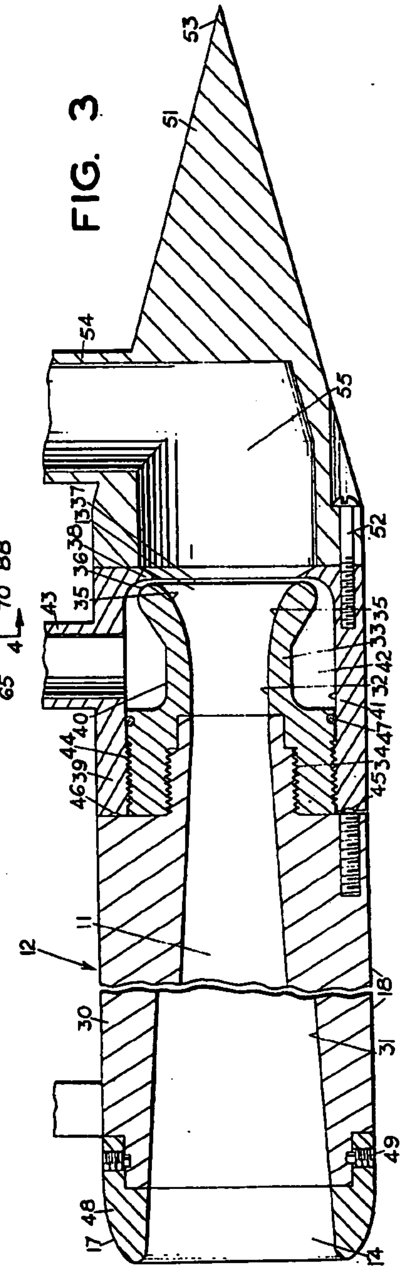


FIG. 3